COAL

AND ITS PRODUCTS

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Two Lectures

DELIVERED IN SUBSTANCE AT

THE CRYSTAL PALACE, SYDENHAM,

ON THE

17TH AND 24TH OF JANUARY, 1867.

BY

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"Οὐθὲν γὰρ οὔτε γιγνέσθαι φασιν, οὔτε φθείρεσθαι τῶν ὄντων, ἀλλὰ μόνον δοκεῖν ἡμῖν."—DE CŒLO, LIB. III. C. 1.

LONDON:
WILLIAM MACINTOSH, 24, PATERNOSTER ROW.

1867.

LONDON:

PRINTED AT THE OPERATIVE JEWISH CONVERTS' INSTITUTION,

PALESTINE PLACE, BETHNAL GREEN.

TO

THOMAS TWINING, ESQ.,

VICE-PRESIDENT OF THE SOCIETY OF ARTS,

These Lectures

ARE RESPECTFULLY INSCRIBED, AS A SMALL CONTRIBUTION

TO THE GENERAL TRIBUTE OF ESTEEM,

JUSTLY PROFFERED

TO ONE WHO HAS BEEN PLEASED TO RENDER

AFFLUENCE AND ATTAINMENT SUBSIDIARY TO THE

PROMOTION OF ART AND SCIENCE,

AND THE DESIRE FOR

THE AMELIORATION OF THE CONDITION OF

HIS FELLOW MEN,

BY HIS OBLIGED FRIEND,

THE AUTHOR.

PREFACE.

A LARGE part of the first, and the whole of the second Lecture were delivered merely with the assistance of a few notes. They were not intended in the first instance for publication. When I was asked to have them printed, I thought it best to write them as nearly as possible as they were delivered. I did not, of course, expect to meet at the Crystal Palace—a popular place of amusement and instruction—an audience who understood much about chemical science, and therefore I only attempted to deal with the subject in a popular manner. I much regret that numerous professional duties have prevented my giving that time and attention to their preparation for the press that I should have desired. Indeed, I had intended, had my time allowed of it, to have considerably enlarged them, and to

have added copious notes. Such as they are, they are now before the public.

I take this opportunity of expressing my sincere thanks to many friends who sent me numerous specimens as lecture illustrations—to Mr. Ansell, of the Royal Mint, Messrs. Clarke and Coste, Mr. Bush, Mr. Keith, Messrs. Roberts, Dale & Co., Mr. Krauss, and last though not least to my good friend, Mr. Johnson, of Basinghall Street.

C. M. T.

THE HOLLIES, CAMBRIDGE HEATH,
HACKNEY, *March*, 1867.

COAL AND ITS PRODUCTS.

LECTURE I.

Ladies and Gentlemen,—When I first accepted the invitation of Mr. Lee, to deliver one or two Lectures on some favourite subject connected with that science to which I have devoted the best energies of my life, it seemed an easy task to undertake, but I must acknowledge that I found no ordinary difficulty in selecting a subject that might prove of sufficient interest to the visitors of the Crystal Palace, to warrant me in asking their time and attention for two consecutive Lectures. The English people are peculiarly a practical nation. They seem to care little or nothing for science, unless they are able to perceive some immediate benefit, which directly or indirectly affects their business or interest. They can understand the steam-engine and electric telegraphy, for these are the practical applications of science. In unfriendly phrase, but with substantial accuracy, a renowned foreigner described the English people as "a nation of shopkeepers." While I disdain the spirit that dictated these words, I yet admit their truth, and glory in it; at the same time, I fear whether the English people are not too

ready to "throw cold water" on the discoveries of science, of which they are unable at once to perceive the utility. Everything must have a beginning, and all great discoveries, as all great systems, have undergone a process of development. Is it not a fact, that, as a rule, the laborious workings of the chemist or physicist entirely fail in interesting the general public? Are not our scientific institutes generally deserted, except the lecture room is metamorphosed into the music hall? In short, does not everything mark the fact that England is a commercial nation, bent on commercial enterprises, and caring for nothing but what concerns commercial interests? And keeping this fact in view, I have concluded that the history of coal and its products cannot fail to interest an audience of English people. For the coal mines are England's gold mines; and their products have furnished, within the last few years, most important branches of human industry.

It is necessary that a nation, to become eminent, should possess some cheap mechanical and material source of wealth and power; and if we seek for the basis of England's greatness, we shall not hesitate, I think, to point to our coal. It may be said, might not other substances do as well? Wood may suggest itself as capable of taking the place of coal. But we remark that a square mile of forest land, covered say by 20,000 trees, each averaging two cubic yards of solid firewood, is about equal to an acre of coal six feet thick; besides which we have scarcely wood enough for the carpenter's requirements, much less for domestic uses. The peat and turf bogs of Ireland, Holland, and

Germany have over and over again been subjected to processes of drying and compression, but nothing satisfactory has resulted from these attempts to render them domestically useful; and, even then, a single acre of coal would be equivalent to three acres of turf of equal thickness. The superiority of coal as a fuel will be at once apparent by this diagram:—

Cubic ft.	Weight.		lbs. of Water.		
1½ of Coal ..	100 lbs.	will evaporate	1200	from the boiling	point.
1½ of Charcoal	11½ „	„	150	„	„
1½ of Wood ..	45 „	„	270	„	„
1½ of Turf	30 „	„	340	„	„
1½ of Lignitel	10 „	„	800	„	„

The amount of power of various fuels is very practically illustrated by the quantity of water a given mass of the material will evaporate, and the weight of the given mass; and here you will see at a glance that 1½ cubic feet of solid wood is only half the weight of an equal bulk of coal, and has only one-fifth the power—for it will only evaporate one-fifth the quantity of water; in the case of charcoal a given bulk has only one-eighth the power.

What a power seems stored up in that coal! What a wonderful force is that "latent light, buried in the earth for long ages, and now brought forth and liberated," as Stephenson expressed it. Think for a moment that the whole powers of a man during a long life is concentrated, as it were, in three and a half tons of coal; and then think that upwards of 100,000,000 of tons are being raised annually in England. We cannot estimate the power, the force of such a quantity. It is calculated, taking the whole of the passenger and goods trains in the British islands, that they travel

as great a distance as the earth is from the sun and half-way back again every year, to accomplish which 7414 locomotives are continually at work. This necessarily consumes a great part of our coal. The "Great Eastern" steam-ship, when in full sail, uses 250 tons per day; and bearing in mind that a sum almost equal to the national debt is invested in railways, we shall appreciate the importance of a fuel in which the smallest bulk performs the greatest amount of work; and, moreover, can easily understand the alarm of a nation at the mere mention of a sudden stoppage of such an important material—for then we should be reduced to the state of a thousand years ago. No longer (as our favourite saying has it) should we be able to annihilate time and space.

But we must remember, whilst it is coal that makes the engine to go, it is coal that makes the engine; so that if the supply of coal in England ceased, there would necessarily be an end to our vast iron manufactures.

The coals of Northumberland, Durham, and South Wales, are considered superior to those obtained from other parts of the British Isles. It is a very abundant mineral, but occurs in much greater quantity on the eastern side of North America and in the valley of the Missisippi, than in any other part of the known world.

The coal measures are the most essential representatives of the carboniferous series, and hence the title carboniferous. They are situated above the old red sandstone, or Devonian strata, from which, however, they are separated by a mass of vegetable remains. The carboniferous system is divided into three distinct

layers or strata, not, be it understood, that these three layers are generally present, inasmuch as they are only very occasionally found, but it is an established rule for geologists to accept the fullest development of a formation, as the type of the system, considering the absence of a group to be due to some accidental cause. These three layers are thus described. First, and lowest, *the Carboniferous Slates;* Second, and central, *the Mountain Limestone;* Third, and above all, the true coal measures, or, as they are termed, *Upper Coal Measures*, in contradistinction to the lower. The first of these groups in the English coal mines is invariably absent, so that there is nothing separating the Devonian strata from the mountain limestone.

Omitting the first two of these groups, I pass on to that with which we are to be occupied, the true coal measures, or uppermost layer. And here I may remark that in England a fourth layer of quartzose sandstone, termed "millstone grit," is often found separating the upper coal measures from the mountain limestone.

When we think of the great depth of coal from the surface, we are instinctively led to ask the question, "How came men to think of digging for coal?" Providentially certain causes have arisen that have disturbed the even layers in which probably the strata were originally deposited, upheaving one part to the surface of the earth's crust. And this may have resulted from an intrusive rock of basalt or porphyry, forced up by the agency of internal heat, completely disarranging the fixed order and horizontal position of the beds. In some cases one end of the coal seam is forced bodily to the surface of the earth, and thus men got a clue to

its existence and position, and were able to work it easily. It is singular that nearly all the coal formations are what is termed *basin-shaped*, that is to say, the strata being disturbed from their horizontal positions, dip down into the earth with long and slanting sides, eventually to meet other long and slanting sides at some common centre. This constitutes what is known as the coal-basin, which is often of enormous extent, and for this reason cannot always be demonstrated—just as a man would never discover by walking over miles of country that the earth was spherical. And here I may mention other peculiarities that may be accounted for by means of intrusive rocks. You can understand that if the coal never deviated from one layer, no matter whether that layer be horizontal or, as is usually the case, slanting, the miner might dig on and on without any hindrance, until the seam was exhausted. But unfortunately such cases are rare, for dislocations occur, to which the pitmen give such euphonious and expressive names, as Dykes, Slips, Faults, Hitches, Troubles, Nips, Wants, Saddlebacks, Baulks, Potbottoms, and the like. In these cases the coal has shifted its position; in one, a part has been raised above another; in a second, a rock has cut entirely through a seam; in a third, a part of the seam has slipped down a short distance, or else, amongst numerous other difficulties a miner has to contend with, he may find a quantity of coal by some strange freak of nature reduced to a perfect powder. Dykes are fissures which are found to traverse the strata, often extending several miles, and penetrating to an enormous depth. These fissures are usually filled with

clay, or the debris of dislocated strata, or basaltic rocks. I was fortunate enough, in a mine I descended at Newcastle in the spring of last year, to see a good example of a slip, which my guide informed me had cost the owner £1200 to get upon a working track again. In all these many difficulties, the same agency that has been of such immense service in uplifting the strata to the surface, has also occasioned the untoward irregularities which are so extremely perplexing to the miner. "It's a good horse that never stumbles;" so it must be indeed a good result that has no ills attending it.

I have now to draw your attention to the origin of these vast tracks of coal. This we gather from the fossils found in the measures—for fossils are nature's hieroglyphics—they tell us, in accents of no hesitancy or uncertainty, the story of ages long gone by, and the curious mechanical changes that time has effected. Indeed, from fossils we collect the history of the world. It is true all we can learn from them is by comparison with existing plants and animals; but nature never deceives us—she has been, and will be, the same through all time. The plants and the animals, as the restorations in the Palace grounds prove, are but modifications of one grand principle, altered to suit altering times.

I need not detain you with any particular account of the *Fauna* or animals of the period. They are not of much importance, save marking the evident introduction of the reptile, or perhaps the passage from the fish to the reptile. These were the days when the Megalichthys, (μέγας, great, and ἰχθύς, fish), with its teeth four inches long, and scales five inches in diameter, was the tyrant monster of the waters. We find also

corals, and about three hundred varieties of shells, and some low organized marine animals; and we also claim this great antiquity for cockroaches, beetles, and grass-hoppers; but these were days, as Hugh Miller remarks, "When no human being had yet left an imprint of his foot on the soil where the coal plants grew." But if the fauna are not of much importance, the flora are of all importance, for these hieroglyphics of nature tell us that coal is the product of ancient vegetation, long long ago passed from the living world, entombed in mud and sand. The story of the origin of the carboniferous formation is one of strange uniformity. Whatever variation may occur in the distinctive layers, the association of vegetable remains is constant. Moreover, if there was any question as to the vegetable origin of coal, the microscope, that revealer of hidden wonders, clearly indicates the elementary tissue of the plant, for slices of bituminous coal may be rendered so transparent as to enable us to perceive and study its microscopic structure. About 683 varieties of plants have been examined and named, not, however, such plants as characterize or form our forests in these latitudes, though bearing in some degree a general resemblance to those of tropical parts. They consisted principally of ferns, bearing the same proportion as regards size with modern ferns, as General Tom Thumb does with the Chinese Chang—the same, but different.

It is a matter of regret that the mutilated state of the fossils render the task of the botanist in classifying them a very difficult one. A few fronds—a few detached trunks—or a few roots—and that is all. And from these meagre specimens we have to gather all that

can be learnt of the long past. The stems are invariably in that state of decay which precedes conversion into coal, being entirely destitute of bark, and usually pressed nearly flat. Many of the views that have been advanced are romantic and imaginative in the extreme; indeed a celebrated French botanist has said, "that all speculations upon the nature of former vegetation ought rather to be referred to the romance of natural history, and have no concern with science." We must accept this remark with certain limitations, for of this it is quite certain, (and the beautiful specimens on the lecture table are illustrations of the fact,) that in the early ages, before man lived, our planet was clothed with a luxuriant vegetation.

I will now just briefly pass in review a few of the more important of the coal plants.

The *Sigillariæ,* (Sigillum, a seal,) so named from the seal-like punctures occurring on the ridges and raised flutings of the stem, is one of the most important of the genera, and includes about 60 species.

They were probably of large size, growing in moist places, consisting of an elegant tapering stem, (hence often the cause of mining accidents,) rising from the ground to a great height, and covered at the top with a mass of bright green foliage; this idea is gathered by comparison with existing forms of vegetation, supposing them similar to modern palms. Huge root-stems too are found, termed *Stigmariæ,* (Stigma, a dot or puncture,) which it is now tolerably certain are only the roots of the Sigillariæ.*

* This fact was originally proved by M. Adolphe Brongniart, who discovered, on examining microscopically the internal structure of a silicified specimen in which the vascular tissue was preserved, that

We are probably better acquainted with the *Lepido-dendron*,(λεπὶς, a scale, and δένδρον, a tree,) than with any other varieties of the coal plants, as many have been discovered almost entire even to the topmost branches. One specimen was found in a Newcastle coal mine, 40 feet in height, and 13 feet diameter at the base. About forty varieties have been described. We find the numerous leaves have decayed away during the growth of the tree, leaving the trunk as though it was covered with scales of a triangular shape; and hence its name. The number of branches varied from sixteen to twenty—and these were covered with large elongated leaves arranged spirally round the stem. The Lepido-dendron is supposed to have its counterpart at the present time in the club mosses, (Lycopodiaceæ,) which are common and of large size in New Zealand. Of this relationship, however, there is considerable uncertainty.*

The common marestail of our ditches and rivers is the pigmy representative of the characteristic plants known as calamites, (calamus, a reed,) so termed from their resemblance to gigantic reeds. In this country they are not more than two feet high, and even those found in the tropics rarely exceed five feet. Botanists are not, however, very well agreed as to their true affinities, for whilst in form and growth there is much general

the organization bore as close an analogy to that of the Sigillariæ as exists between the roots and trunks of certain Dicotyledenous trees.—Vide "Mantell's Fossils," Bohn, p. 36.

* Professor Corda, in "Skizzen der vergleichenden Phytotomie vor-und jetztweltlicher Pflanzen-Stämme," states his opinion that they have no connection whatever with the lycopodiaceæ, but that they are far more closely allied to existing crassulaceæ.

similarity, there are many essential points of difference. I need not detain you with any further notice of the fossil flora, save to mention, amongst others of more or less importance, are to be found small radiating plants with star-like whorls of leaves, not however peculiar to the coal measures, but existing in the oolite and lias, termed asterophyllites (ἀστήρ, star, φύλλον, a leaf.)

And what does this brief review clearly indicate? Just as one has said, the discovery of ancient armlets and rings betrays the fact that the spot where they were found was originally a haunt of man, so the coal plants tell us, that in that mysterious beginning when God created the heavens and the earth, that time about which we know nothing—we care not to know, we cannot know—there were sown by the Almighty's hand the seeds of huge forests, that should spring up and clothe the earth with a luxuriant vegetation, even before the days of the monster fish, "that moving creature that hath life," or the creeping reptile—ages upon ages before even Adam dwelt in Eden. And these huge plants were ultimately to form enormous beds of a mineral that hereafter should be the mainspring of England's prosperity, the very handle of her wealth in this the nineteenth century. The thought is a strange one, that our acknowledged national superiority was laid, formed, predestinated, even before the sun shone upon the earth—that in remote periods of the earth's history these forests sprang up and flourished, to furnish the future lord of creation with a blazing ingle and a mighty instrument for accomplishing the vast purposes which knowledge would unfold to him. And so it seems to me that coal

is a deposit placed in the faithful keeping of the earth, to be developed whenever and wherever the increasing intelligence and civilisation of man require it, as a means of diffusing their beneficial influence. And this I take to be the meaning of its universality.

The conclusions geologists have arrived at concerning those ancient forests are interesting. They probably much resembled the extensive and roughly grand forest districts that exist in Australia, Van Dieman's Land, New Zealand, Norfolk Island, and other places as yet uncultivated, and certainly unlike anything existing in England at the present time. Humboldt describes the region occupying the great river basins of the Orinoco, and the Amazon in South America, (a district twelve times as great as that of all Germany, as so truly impenetrable that it is impossible to clear with an axe for more than a few paces any passage between trees of eight or twelve feet diameter. Huge trees are found at every foot distant, and even the small intervals are crammed with an undergrowth of plants, a small passage only existing here and there as paths to the homes of wild beasts. Huge tree-ferns, somewhat resembling those we read of as flourishing in Norfolk Island, were striking features of the primeval forests, trees of a size perhaps equal to the *Wellingtonea Gigantea* (the bark of which was before the late fire a conspicuous object in the Palace, and the loss of which we all so deeply deplore.) Many climbers and twiners too might have been seen clinging for long distances from plant to plant; and dark brown coloured ferns, growing in rich luxuriance. And such seems to have been a coal forest. The atmosphere at this time was probably damp, and what we

understand as muggy, but there seems no very good ground for asserting there was much difference in the temperature. If it had been much warmer, Dr. Hooker concludes that probably we should meet with some fossilized remains of flowers, which we do not; and if it had been colder, probably the trees would not have assumed such a gigantic size as they undoubtedly did. At the same time it is right to state that many eminent authorities are of opinion that the heat of the period was considerably greater than at the present time, and more approaching that hot vaporous atmosphere which must strike all visitors to the tropical department of Kew Gardens, and to which the authorities evidently attach so much importance, by their constant reminders to shut the door, as though that close air was like a beast at the Zoological Gardens, always wanting to get out but requiring to be shut in. Such an atmosphere we all know will stimulate ordinary fruits and plants to assume a gigantic size, just as artificial heat is employed now-a-days to raise the colossal turnips and giant carrots for our shows.

And thus we arrive at an imperfect though not altogether an incorrect notion of nature during the coal vegetation. We see, perhaps, a huge island rising out of the vast ocean, (for it is likely that at these times there was a different arrangement of land and water,) and this island covered with a uniform forest of ferns, with much less variety of vegetation than is now found, with a warm, or at any rate a genial equability and continuity of climate. It was a time when there were few bright flowers to enliven the dull aspect of nature, and but few fleshy fruits, for man did not exist to enjoy them;

it was a time when there was no green eye-relieving grass; it was a time that lacked life, for only a few crustaceans and fishes seem to have been called into existence. It was a time of silence and stillness, and apparent death; without the merry song of birds, the roar of animals, or the voice of man. Further than this we dare not go. Pretty landscapes are presented to you in geological works, of these remote times of the world's history. They, however, lack reality, for they are only the imaginative, though perhaps to a certain extent truthful pencilings of a modern artist, and not the studies of a painter of the ancient world. Full well I remember my reflections whilst wandering through the underground streets of a coal mine. I was in the homes of the mighty dead—the catacombs of vegetable giants. I was treading the streets of innumerable forms of vegetation, that waved luxuriantly in the warm breezes before ever the seeds of the trees in Paradise had been sown. I was beholding mysteries greater than the Pyramids—with an earlier antiquity—the crystallized remains of a forest older than the Ichthyosaurus.

And now let us go a step further; and the question arises, how can we account for the *position* and *formation* of the coal beds? It is certain the changes were peculiar, as the land is not entirely covered with coal; nor, secondly, is it found in all periods. Two favourite theories have been advanced. The first is, that the coal forests grew *on the spot* where the coal measures are found; the second, that they grew at a *considerable distance* from the coal beds, and were drifted down by rivers, with a quantity of mud and sand, into estuaries. The first is

known as the "Terrestrial Theory," the second, the "Drift Theory."

The terrestrial, or peat moss theory, supposes that the plants accumulated in dense jungles for many years; that then the whole land by some agency or another sunk down and formed the basin of a vast lake, which was eventually overlaid by deposits of mud and sand, carried by rivers into the lake; and then the ground was again elevated, again the scene of luxuriant vegetation, and again submerged, and so continual alternations of elevation and submergence, corresponding to the number of beds of coal.

The theory of the drift, however, supposes that huge trunks and masses of vegetation, gathered up by periodical inundations, were carried by the agency of the rivers into vast estuaries, there being deposited as drift or silt, other rivers at the same time bringing mud and waste material.

It is much to be deplored that disputants labour for victory rather than for truth. To decide which is the correct hypothesis, let us appeal to existing nature. We find rivers at the present time (the Nile for example) subject to overflowings, when immense masses of vegetable matter are carried down by the tide until stopped at the Delta, which in this manner becomes choked with vast masses of decaying vegetable matters. Such examples favour the theory of the drift. At the same time we notice that this view does not account for huge stems found in the upright position as they grew, which fact can only be accounted for by the theory of submergence. So then, to arrive at a satisfactory conclusion, we must unite both of these hypotheses,

and then we shall be nearer the truth than by confining ourselves to the limited observation of a few, who, however great, are always apt to carry their respective notions a little too far, forgetting how liable they are to err in their conceptions of a science necessarily so imperfect as geology.

I have thus attempted to prove the vegetable origin of coal. I will proceed to sketch the changes this vegetable matter underwent during its conversion into coal.

The component parts of all vegetable matter are carbon, hydrogen, and oxygen, with a certain per centage of earthy matter and alkalies, (the hydrogen and oxygen being to a great extent in the form of water.) By means of pressure and exclusion from the atmosphere, a large quantity of the water in the wood is got rid of, and further, if by any means the carbon is prevented uniting with the oxygen during the natural process of decay, it becomes preserved with the alkaline and earthy matters; but other changes now ensue, the external form of the plant is gradually lost, and the general texture becomes confused, and in this state it would remain for a long period without any further change, forming, when exposed to the air, that imperfect fuel called Lignite.

We shall better understand the change wood undergoes in the formation of coal, if at the same time we compare it with the chemical constitution of other fuels. Taking then wood, peat, lignite, and coal, analysis proves that the proportion of hydrogen remains the same in each. In peat there is about 10—20 per cent of ash, in lignite 8—15, whilst in good coal there is generally less than 5 per cent; again, there is about 52½ per

cent of carbon in woody fibre, about 56—70 per cent in peat, but between 80 and 90 per cent in coal; whilst of oxygen there is upwards of 40 per cent in woody fibre, whilst there is rarely 10 per cent in coal. We learn from these few facts, that in coal there is double the amount of carbon but considerably less oxygen than there is in wood. Now I said the proportion of hydrogen remained nearly the same in all, but in the relationship of the hydrogen depends the difference between the other fuels I have named and coal; for whilst in peat, wood, and lignite, the hydrogen is in union with the oxygen, in the form of water, in coal a part of the carbon is united with the hydrogen to form carburetted hydrogen; in addition to which the texture becomes closer and more compact. The more perfect these changes are, and especially the more completely the carbon has united with the hydrogen, the more perfect is the mineral fuel, and the more valuable the coal.

It will be impossible to enter fully into the varieties of coal. All true coal, it may be said, is entirely free from water, and the best coal produces but very little ash. A good specimen will only yield 1 or 2 per cent, though I have analysed inferior articles which yielded 32 per cent. And here I must express my best thanks to my very kind friend, Mr. Johnson, of Basinghall Street, for lending me the beautiful collection of the various coals from Newcastle, Scotland, Wales, Derbyshire, Yorkshire, and Cumberland, which I have placed on the lecture table, and which are well worth a careful inspection. For general purposes we may divide coal into bituminous, semi-bituminous, and non-bituminous.

That very remarkable variety known as cannel, or candle coal, (because it takes fire like a candle,) is the best example of the bituminous variety. This coal yields a large quantity of gas, and is also capable of being worked into ornaments. The fields of Newcastle, Durham, and Yorkshire yield the bituminous variety.

The steam, or semi-bituminous coal, obtained chiefly from North and South Wales, from France, Saxony, and Belgium contains very little volatile matter and bitumen, but a great deal of carbon, and is well adapted, for the manufacture of iron.

The non-bituminous variety, or anthracite, is almost exclusively carbon; and whilst it takes fire with great difficulty, gives out great heat when fairly ignited.

These, however, are all varieties, and but modifications of these ancient forests of which I have been speaking.

We are now bound to ask the question, how long will the coal last? England claims that title now, once claimed by Rome of old, "the Mistress of the World." When her coal fields are exhausted that title will be buried in the empty coal pit. When the coal is worked out I leave you to imagine the result; I forbear—I should dread to attempt to sketch it. Now we have heard it said, surely some cheap and abundant substitute will be discovered long before the day when the last ton of coals is drawn from the pit. But you will note that the discoveries of science, upon which such people depend, have no tendency towards dispensing with coal, but of increasing, doubling, trebling its power, and multiplying its uses. Be quite sure the water and windmill cannot compete with the steam-engine now,

and there is not much chance of their doing so a hundred years hence. Moreover, if science tries to supersede the use of coal, she tries to supersede that upon which our greatness and national superiority depend· England has, excepting America, more coal and better coal than all the world; and here lies her strength, that she has with undaunted energy worked it and used it, whilst other nations have let it remain idle, or comparatively so. I do not mean to ridicule the notion that some substitute for coal may eventually be found, but what I remark is, that at present the discoveries of science rather tend to a fuller development of the use of coal than to any substitute for coal. Remember this fact, that a hundred millions of tons were raised last year, and that the demand has increased sevenfold within the last sixty years. From 1856—60 76,213,409 tons were used as the average per year. During the next five years, from 1860 to 1864, 93,709,781 tons was the average, or one-fourth increase; in 1865, 98,150,587 tons were worked from the 3,256 British coal mines;* and from unpublished statistics, I gather that upwards of 100,000,000 tons were raised in 1866.

The quantity of coal consumed increases then at about the rate of 2·6 millions of tons per annum, that is very nearly in accordance with Sir William Armstrong's calculation of 2,750,000 tons. Mr. Bedlington, of the Rhymney works, in South Wales, considers that the maximum consumption has been reached. I am at a loss to understand on what grounds he bases this

* Mineral Statistics: R. Hunt, F.R.S.

opinion. It seems to me that the quantity required will necessarily be greater every year. Mr. Jevons, however, calculates that "if our consumption continue to multiply for one hundred and ten years at the same rate as hitherto, the total amount of coal consumed in the interval will be 100,000 millions of tons." This, however, is probably an exaggeration, for it is well known that certain machinery is now manufactured on the continent, which serves to relieve rather than drain our coal resources. But for all this, and whatever existing minor prophets may make out of numbers, and dupe those who are always too ready to be duped, the world has not come to an end yet, nor is there any very visible appearance of its doing so. Plenty of railways have yet to be made, and steam-ships to be built; sailing vessels are gradually disappearing from the ocean, and that poor horse who drags the boat on our canal must one day give place to the untiring engine, and so more coal will be required as more steam is used. Moreover, as I shall point out in my next lecture, new articles are daily being manufactured out of coal. It is truly then a question of great importance—how long will our coal last? And here I may remark, that it is a question every now and then being discussed, and then allowed to drop for a time, but only to be discussed again. Fuller, in the year 1661, describes what an immense amount of coal was raised in England, viz., 200,000 chaldrons. I have been amused at reading in Dr. Watson's "Chemical Essays," a book of profound wisdom, the notions that men entertained in his day concerning the probable exhaustion of coal. He says, date 1779, "certainly

the amount of coal annually consumed is enormous, viz., as much as 586,845 chaldrons;" and he adds, with apparent wonder and amazement, "what great excavations must be annually made in these islands!" What would the great Dr. Watson think if he could come amongst us again, and find one hundred and fifty times the quantity being used. We have good reason to believe that the Newcastle coal pits were worked in the time of the Romans, for in Wallis's "History of Northumberland," he gives an account of coal cinders having been found at the bottom of the foundation of a city built by the Romans in that county. Probably indeed coal was dug by the Britons before the Roman invasion, but this of course is to a certain extent conjecture. At any rate it was in common use in England in the reign of Charles the First, that is about the year 1628, from which time every now and then men have eagerly discussed that question, again asked in 1867, "How long will our coal last?" Considerable difference is to be found in the calculations of various scientific men.

In the year 1801, Mr. Bailey predicted that the Northumberland coal fields could only last two hundred years. Professor Buckland, in 1830, calculated that all the coal would be exhausted in four hundred years; Professor Thompson, also in 1830, gives us one thousand years; Mr. Hugh Taylor calculated 1727 years; Sir William Armstrong, in his speech as President of the British Association, 1863, declared two centuries to be the probable limit of the coal fields; Mr. Jevons, in 1865, published an elaborate work, in which he concludes, "there is a fair chance of

coal being exhausted within a century." This view was taken up by Mr. Mill, in the House of Commons, who not a little alarmed the nation by dwelling on the fact that we were fast consuming the stock-in-trade of our posterity; and then Mr. Gladstone, ever ready to embrace an opportunity for a long speech with calculations suitable to the brain of a Gladstone—and a Gladstone only—proposed to meet the difficulty by reducing the national debt. The area of coal in the British Islands, according to Professor Ansted, is about 6000 square miles, and we are told about 4,480,000 tons can be extracted on an average from each square mile. If this is correct, and we calculate 100,000,000 tons per year, we shall have enough for the next 268 years. Such a calculation coincides with those of many authorities, and amongst them Mr. Hull, a man of vast practical knowledge and experience. I do not, however, attach much worth to such calculations. On the one hand, it may be said that it is impossible to say how many coal fields yet remain to be discovered. It is true some important shafts have lately been sunk in the reputed dead ground at Priors Lee, in Shropshire, but this is an accidental matter, for there is no probability whatever of absolutely new sources of supply being discovered, if geological evidence is worth anything. On the other hand, it may be said that such a calculation entirely overlooks the increasing rate of consumption; but then I have allowed for this when I reckon the coal area at 6000 square miles, when it is nearer 8000, and also in reckoning 4,480,000 tons as able to be worked from the square mile, when 6,000,000 would be perhaps more correct. We may fairly

reckon that there is twenty-five times the quantity of coal in America that there is in the British Islands, but not more than one-eighth in Belgium, and one-fifth in France. Now Mr. Vivian, M.P., in the endeavour to quiet the excitement on this question, asserted (and here I speak from memory) that there were 83,000 millions of tons within 4000 feet of the surface, and he said no difficulty would arise, either from pressure or temperature, in working it at that depth. I have been down a very deep coal-mine in Newcastle, and I must say that I felt my breathing was somewhat embarrassed, and calculating that the thermometer rises one degree for every forty-five feet, we should have as great a rise as 89° for the 4,000 feet. I can perfectly understand that certain improved systems of machinery, asthe process of rarefaction, may obviate the difficulty of working at a temperature of 120°, but I cannot see how any means can obviate the pressure of superincumbent strata, nor produce suitable supports for the roof of mines 4,000 feet deep—when at a depth even of 2000 feet a bar of cast-iron a foot square was broken in two by the pressure. I feel confident in stating my opinion that perhaps the temperature, but certainly pressure and chances of accident, would prevent our being able to work coal at this distance from the surface; and after all the practical question Englishmen will study is—will it pay? For to open fields 3000 or 4000 feet deep will require an outlay of a quarter of a million. Taking, however, all facts into consideration, I can see no need for unnecessary alarm. Calculations generally give us about 300 years—that will last your time and mine. Do not let us trouble ourselves about

substitutes; remember that old but flippant saying of a well-known politician, "Posterity never did anything for us, and why should we do anything for posterity." *

But at the same time a certain prudence should be exercised in the use of this precious mineral. The question arises, should we export coal? As much as 9,000,000 of tons were exported in 1865, that is about 1,700,000 more than in 1864; and I find 34,857 tons were exported from Newport in November, 1866, against 21,687 tons in November, 1865. Would it not be only right and fair, and moreover a reasonable mode of meeting the difficulty, to levy a tax on exported coal? We have no right to give others what we want ourselves. We are cheating our children when we send coals to Prussia, and Denmark, and Spain, and France, and Holland. A day may come when we may want it badly enough, its want may retard our civilization, and point me to an Englishman who would for a moment like to be beaten in that great race of competition by his Yankee brother. The history of nations is one of rise and fall—all tell one story. Britain now is *Great* Britain—great in science—great in commerce—great in inventions—great in letters—great in art—great in possessions; but, depend upon it, Great Britain will not be *Great* Britain when her coal seams are exhausted.

It is a sad reflection that 1000 lives are annually

* I do not mean to say that I approve the sentiment; I am strongly of opinion that Mr. Gladstone took a correct view of the case when he justified the necessary consumption of coal, but condemned the injustice of bequeathing to our posterity the national debt.

sacrificed in working coal. As many as 9916 people met a violent death from the years 1856 to 1865; and but lately we have been startled at reading the accounts of two terrible colliery accidents by which the destroying angel with terrific sweeps drew into his grasp four hundred souls. Such a wholesale loss never occurred before. I earnestly hope colliery owners will take care it shall never occur again. The causes of death generally arise from falls, accidents in the shaft, or as in these melancholy instances, from explosions of fire-damp. During the last fifteen years, until the last year, the number of deaths from mining accidents had steadily decreased. As many deaths occurred during 1866 from explosions of fire-damp, as occurred for nearly the five previous years from the same cause. When we reflect on such disasters as the Oak's colliery explosion, and that in North Staffordshire, it is cheering indeed to find that so many are ready to aid a subscription list already amounting to a large sum, headed by the munificent sum from the noble donor who is ever ready with queenly magnificence and liberality, to help the fatherless and orphans in their affliction—one who it matters not under what trying circumstances herself, finds a delight in wiping away her subject's tears when her own eye is dimmed, and comforting the widowed heart though her own be scarce relieved from its bereavement or its pain.

I shall not pretend to enter here into the history, or the causes and prevention of mining accidents—save one, with which as a chemist I necessarly feel interested—those arising from explosions of fire-damp.

Now the place occupied by water in the wood (of

which I have already stated the existence) is filled up by gas—fire-damp in the coal.

Sometimes when a mass of coal falls, a terrific invasion of fire-damp suddenly ensues, termed a "blower," that is almost certain to be the cause of an accident should an unguarded light be near; it is sad to think how many pitmen are thus buried in ready dug graves. I shall not enter now into any details concerning the chemical constitution of fire-damp; suffice it to say it is chiefly composed of carburetted hydrogen, with variable quantities of nitrogen, and carbonic acid, &c. I would rather spend the few remaining minutes of my time in endeavouring to answer a practical question of how these sad accidents may be prevented. I venture to propose—

1. Thorough Ventilation.
2. The exclusive use of the Davy Lamp.
3. The employment of Ansell's Indicator.

If a "blower" occurs, and the ventilation is good and the men use safety lamps, there need be little fear of a bad result, but if naked candles are used and the mine is badly ventilated, an explosion is certain to happen.

The principles of ventilation are easily explained, the difficulty is practically to apply them. It consists in having two apertures, one for the inlet of pure air and the other for the exit of the foul air. This is effected in a coal mine in one of two ways.

1st. Providing the pit with two or more shafts. The fresh air goes down one, the *downcast* shaft, and having travelled through the streets of the coal mine, and

supplied fresh air to the workers, goes off as impure air, at the *upcast* shaft. Now, it may be asked, what means are adopted so that the air should always go the way we want it to go, and never reverse its path? This is prevented by a furnace, which is kept continually burning at the bottom of the upcast shaft; warm air being lighter than cold air, always ascends. This is the principle of lamps and fireplaces. The warm and impure air ascending through the chimney may be compared to the upcast shaft of a coal mine, and thus escapes; the windows, doors, and crevices representing the downcast shaft, where the pure air comes in. This will, I think, be easily understood by reference to the following experiment. These two iron pipes may represent respectively, the upcast and downcast shaft of a coal mine. I place underneath one pipe a spirit lamp, to represent the furnace of a coal pit. And now notice the air rushes down one pipe, which is evident by the flame from this torch being drawn downwards, whilst it escapes from this side under which I placed the lamp, as you also notice by the direction of the flame. I cannot forget that I once had the disagreeable pleasure of descending the upcast shaft, which is thus filled with the impure air. This is a famous trick of the banksman to cockney visitors, with the intention, I presume, of giving them a good dose to begin with, and evoking a proper sympathy for those below, by answering liberally to the numerous calls of "Pay your footing." I never felt so wretched in my life as when I was descending that coal mine. I had clothes on that did not fit, for a pitman's dress, though useful, is certainly neither

comfortable nor ornamental. I was in an atmosphere so stifling that I could scarcely breathe—hanging in a corve over a tremendous furnace, with half a ton of coals upon it—sinking at a terrific pace into a warmer and fouler gloom and a more fiery darkness—and the deeper I went the hotter it became. It was a terrible feeling. If you want to know more about it, go and try it.

But, unfortunately, to sink a coal-shaft is a great outlay, costing about eight or ten thousand pounds; and hence a plan is adopted of dividing one shaft into two or more compartments by means of woodwork, termed "a Brattice." The fresh air goes down one compartment and up the other, and so the ventilating current is fully established. I can illustrate this by a simple experiment. If I place a chimney glass over this candle, it will go out; and necessarily, because there is only one opening. If I however raise the chimney, as in a lamp, leaving a free opening at the bottom, the air can gain admission from below to feed the flame, and then will escape above. I can prove this by the direction of the smoke from this taper that I have just extinguished. Now I wish you to imagine that this chimney is the shaft of a coal pit. This candle will serve two purposes—first, as the furnace at the bottom of the shaft, and secondly, as a proof of the constant supply of fresh air, because, where a candle is able to *burn* freely, there a man is able to *breathe* freely, for what puts out a light destroys life, and vice versâ. I have already shown you, that if I close the bottom of the glass, the candle will go out; but now, if I put a partition in to divide the chimney into two channels,

you will perceive the candle will continue to burn, though its flickering may show us that it has some little difficulty in deciding which way the fresh air is to come down, and the foul air go up—but still this current of air exists, and as you see continues to exist, for our candle goes on burning. This partition is to the chimney what the brattice is to the shaft. That light I have said may be compared to a man in the pit, for both require fresh air. But suppose, by some accident, (not an impossibility, as recent mining accidents have proved,) the brattice work is destroyed, the poor miner is deprived of fresh air and his life, just in the same manner as this candle when I remove the diaphragm becomes extinguished. Let proprietors of mines remember, "Stinginess is false economy." Every mine should at least have two shafts.

Secondly. It should be a rule that the Davy lamp should be exclusively used in coal mines. The Davy lamp only—and in all mines. That seemed to me a foolish order, that lightning conductors should always be kept on board ship, and put up directly it was perceived that a storm was near at hand; of course, as might be expected, they were never up when they were wanted. Just so, if Davy lamps are only used when it is supposed the mine is in danger, they are never in use when an explosion occurs.

The chief constituent of all pit-gas is light carburetted hydrogen (C_2H_4). Now it requires admixture with a certain quantity of atmospheric air to render it dangerously explosive. If I mix one part of coal gas and one of air in this bottle, and apply a lighted taper, it merely burns with a pale blue flame; but the

case is altered if I mix seven parts of air with one part of the gas. . Listen to the rumbling explosive noise. And this illustrates on a very small scale, what would happen on a large, should the gas come in contact with a naked flame. Now Sir H. Davy found that this gas had an exceedingly high kindling point, requiring a flame to ignite it, and he found, moreover, the flame became so cooled by passing through a cylinder of wire gauze that it would not set fire to the surrounding gas. The gauze used contains about four hundred apertures to the square inch. The fire-damp indeed may burn within the cage so energetically as to heat the wire to redness, and yet neither the flame nor the heated iron will explode the gas in the outside. I will illustrate this by placing a Davy, of which I have here a specimen, in this glass jar, and gradually admit a little coal gas from below. The flame at first appears elongated, and then it is extinguished, the whole interior being filled with a burning mixture of the gas and air. I will leave off introducing any more gas and allow the atmosphere to become purer, and now we find the wick is re-lighted.

It seems generally supposed that if a mine is in a dangerous state, the miner may safely continue to work, provided he uses a Davy, but this is not the case, for if the air is in any way explosive, it is not fit for respiration, hence the lamp is only an indicator of the state of a mine, and not on any account for the purpose of allowing the miner to continue his duties in an impure atmosphere. If a Davy is not used a small quantity of gas renders the atmosphere explosive, and the dreadful effect of such an accident is unhappily too familiar to

those who read the daily papers. Such an explosion is terribly violent and blows everything before it. The woodwork is shattered and broken into small pieces, and "living beings," says a popular writer, "are projected bodily through frameworks of wood, just as if they were hard solid and inanimate substances;" and what a frightful sacrifice of life! What a cry is that heard from wives, now widows, and children left orphans. We may be thankful that science has the power to a great extent, if only her suggestions were acted upon, of preventing such accidents and calamities. In Newcastle it is a generally received opinion that the safety lamp was discovered by George Stephenson, and hence the miner terms it, "The Geordie Lamp." I have carefully endeavoured to examine the relative claims of Davy and Stephenson, and feel convinced that it is one of those rare, though not impossible cases, where the two in a race reach the goal at precisely the same moment. Neither, however, thought fit to patent it, but with that open-heartedness and desire for others' benefit and their country's glory, freely gave up all money interest in their invention. Those words of Davy's, when asked to patent the lamp, would well have fitted the mouth of a Stephenson, "I have enough for my views and purposes, more wealth would not increase my fame or my happiness."

I would very briefly, in conclusion, draw your attention to the discovery of Mr. Ansell, of the Royal Mint, whose patent Indicator is a most beautiful application of the "diffusion of gases," for a full investigation of which we are indebted to Professor Graham. Its success in practice of course is to be seen, but it

claims the attention of scientific men, and the mining world especially, for its great ingenuity. It would have been a delightful task for me, had time allowed of it, to have traced the history of this instrument until it arrived at its present state of perfection. I must here beg leave to thank my friend, Mr. Ansell, for his great kindness in lending me his apparatus to illustrate this lecture, and I shall also take this opportunity of thanking him for the extreme courtesy he displayed in showing me numerous experiments, which proved to my mind most satisfactorily the value of his invention. It is easily explained, in Mr. Ansell's own words, "It's no secret, it's perfectly simple; my boy understands it as well as I do."

The instrument consists of a small chamber covered with a slab either of biscuit or marble, the biscuit being used for cases of rapid and the marble for the slow diffusion of the gas. Mr. Ansell formerly used an india-rubber balloon as the gas chamber, which plan however he has now entirely abandoned. Attached to this chamber is a syphon filled with mercury, the rise or fall of which is determined by the amount of gas which is in the chamber; at the opposite end of the syphon is a little glass bulb, (which, however, Mr. Ansell thinks of dispensing with, and for sundry reasons using a straight piece of glass tube,) fastened into which is a needle with a platinum point. The object of this is to show when the mercury has risen sufficiently to touch the point. At the very moment this happens, contact is made with the battery, which converts this soft iron into a magnet, which, by attracting its keeper, rings the bell. Now, when the atmosphere becomes charged with car-

buretted hydrogen, (the gas which I am now admitting into this large bottle that I have covered over the indicator,) in accordance with the law of diffusion passes through the porous plate into the chamber, and so forces the mercury up in this arm of the syphon until it comes in contact with the platinum point, when the union with the battery being complete, the bell, which may be in the office at the surface of the mine, rings, or if connected with a magnetic needle, the needle instantly moves. Mr. Ansell informs me it will clearly indicate five per cent of fire-damp.

Here, too, is a portable form of the instrument Mr. Ansell has lent me, which the viewer can carry in his pocket when he is going his rounds.

A more refined application of science than this we rarely see. Let us hope its general use may not be delayed until a few more accidents have occurred. It is sadly to be regretted that Englishmen are so apt to view all the new discoveries of science as an unneccessary opposition to their preconceived opinions, and will never admit innovations until circumstances force it upon them; but then let us give them their due, having fairly imbibed an idea, they are as slow to part with it as they were to take it in.

I hope in my next lecture to deal with the products of coal.

COAL AND ITS PRODUCTS.

LECTURE II.

"*Per.* I have heard it said,
There is an art, which, in their piedness,* shares
With great creating nature.
"*Pol.* Say, there be;
Yet nature is made better by no mean,
But nature makes that mean: So, o'er that art,
Which, you say, adds to nature, is an art
That nature makes
* * * * * *
This is an art
Which does mend nature—change it rather; but
The art itself is nature."—(*Winter's Tale*, Act iv., Sc. 3.)

THESE words, the bright conceptions of that immortal poet who wrote for all time, I accept as the text of my lecture to-day. They are strangely appropriate. There is a product collected during the manufacture of coal gas, called coal tar, or crude coal-oil. A few years ago it was a valueless article, indeed it became such a positive incumbrance at the gas-works, that the companies would have paid men to have carried it away. But here chemistry steps in—and by simple appli-

* Diversity of colour.—Valpy's Edition of Shakespeare.

cations of the chemical art, renders that useful which before was useless. From this black dirty coal tar, is produced now-a-days the beautiful colors, mauve, magenta, and the like.

> "There is an art, which, in their piedness, shares
> With great creating nature. . . . . . . This is an art
> Which does mend nature—change it rather ; but
> The art itself is nature."

Keep these words in view, and you will see how they fit in with my lecture to-day.

I perceive amongst my audience this afternoon some gentlemen who occupy important positions in the scientific world, and who know probably a great deal more about this subject than I do. I thank them much, very much, for the favour of their attendance. I would beg to remind them, however, that I only dare attempt to treat the subject popularly; and I must trust to their kindness, with which I am not altogether unacquainted, to trace the omission of much important and interesting matter, not to ignorance on my part, but to the general necessities of the case.

Dirt has been defined by a great philosopher to be "matter in a wrong place." The definition is a good one, and strictly correct. It is the ambition of the chemist to take the dirt out of the wrong place and put it in the right. I know of but few illustrations more wonderful, to strike those unacquainted with the bearings of modern chemistry, than its power of utilizing waste; for chemistry, ever casting a watchful eye over matter, has taught us that there is no such thing as waste. "Waste material" are words not to be found

in the dictionary of the chemist. For chemistry, when applied to, took the waste coal tar and changed it into costly dyes.

If we burn some coal in a retort, the oxygen present acts like the oxygen in that fire. A part unites with the hydrogen to form water, and the remainder with a little of the carbon to form carbonic acid. The oxygen, however, is soon all gone, and then the hydrogen divides itself into two parts; the one, unites with the carbon to form the gaseous and liquid hydrocarbons, the other with the nitrogen to form ammonia.

When we distil coal we obtain gaseous products—a watery portion—and lastly, the crude coal-oil or tar. It was a saying of the older chemists, that air, oil, water, and earth, (that is the carbonaceous residue, "or caput mortuum," as they called it,) were the general *elements* of organic bodies. It is strange how, from the first, the true meaning of that word element has been misunderstood; had they said that air, oil, water, and earth were the general *products* of organic bodies, they would have been correct.

The history of coal gas is instructive. It supplies us with an admirable illustration of that process of development which every discovery undergoes. It is a law regulating all discoveries—all systems—that nothing starts into full growth at once. To reach the topmost pinnacle, we must go step by step up the ladder; we cannot with one bound go from bottom to top. The Persians long ago discovered gases issuing from the soil, to which they set fire, and then worshipped them. In the year 1659, the attention of Shirley was drawn to a burning well in Lancashire; many, and in one sense

correctly, attributed the phenomenon to superhuman agency. Shirley, however, found the key to the mystery when he discovered coal in the vicinity of these burning wells, to which he attributed their existence. But he made no practical application of his great discovery; he and the rest of the world were satisfied then with their tallow candles. In the year 1733, nearly eighty years after Shirley, Lowther arranged pipes in the ground in such a manner that he was able to burn the gas at some distance from the spot where it emanated from the earth. Six years after Lowther's experiment, Dr. Clayton, the Dean of Kildare, for the first time distilled coal, obtaining what he termed "an incondensible spirit," which was the gas. The result of his experiments are published in the Royal Society's Transactions for 1739. He there describes very accurately the experiments he made, and appears to have been sorely troubled and perplexed with "the spirit" that came off, "which," he says, "I could no ways condense, but it either forced my lute or broke my glasses." After this he collected the gas in bladders. "I then filled a good many bladders therewith, and might have filled an inconceivable number more, for the spirit continued to run for several hours, though the quantity of coal distilled was inconsiderable. I kept this for a long time, and endeavoured to condense it, but in vain; and when I had a mind to divert strangers or friends, I have frequently taken one of these bladders and pricked a hole therein, compressing gently the bladder near the flame of a candle, and when it once took fire, it would continue flaming until the spirit was done, which was the more surprising because no one could

discern any difference in the appearence between this bladder and one filled with common air."

Invaluable as was this discovery, pregnant with future importance, Dr. Clayton contented himself with making it a plaything "to divert strangers and friends."

Dr. Watson, who at the same time occupied both the chairs of divinity and chemistry at Cambridge, in the year 1761 distilled some coal, and passing the gas through pipes, burned it for the illumination of his room, and from all accounts successfully; but unfortunately, the gas at this time being unpurified, produced so much annoyance, that in summing up his essay on coal gas, he considers its escape into the atmosphere an argument against the use of coal altogether. Gas had now been known upwards of a hundred years. It had been examined by many great scientific men, and yet for all that, (and it seems strange to us who live in days of such vast progress,) they were satisfied to leave things just as they were. We must remember, however, the age required nothing more. Necessity is the mother of invention; and the genius of the age was not quickened by necessity. In the year 1786, Murdoch pointed out how gas might be utilized. He built a gasometer, burnt it regularly in his house, and conveyed some to the houses of his friends by means of leaden pipes. And yet scientific men paid very little attention to it, and no one thought of following Murdoch's example. About this time Mr. Murdoch removed from Cornwall to Ayrshire, and again constructed a gasometer for his private use. This time, Boulton and Watt, the proprietors of the great Soho manufactory at Manchester, paid Mr. Murdoch a visit, and ordered him to construct a gas-

ometer on their premises, which excited a little curiosity by attracting a few idle crowds, (who are always pleased with novelties,) and a little, though a very little attention from men of science. But the great world without, whose due appreciation of a need is necessary for the success of every grand discovery, seemingly cared nothing about this wonderful development of human industry; indeed, it is strange that at this very time the inventive genius of London was spending itself upon some improvement for obviating the snuffing of candles.

It was about this time the invasion of Buonaparte was expected, and men were necessarily occupied with the arts of war rather than those of peace. In the year 1802 the rejoicings for the peace took place. Boulton and Watt determined to illuminate their factory with gas. And from this day popular feeling was excited, and an enthusiastic crowd declared there was no light equal to coal gas. Everybody that possibly could went to see this spirit of coal. Night was turned into day. The newspapers wrote flaming articles upon its superiority to all existing forms of illumination. Advertisements appeared in every paper from one or another willing to construct a gasometer for private use. All the great manufacturers adopted coal gas. And every boy made it a holiday amusement to distil coal in a tobacco pipe.

Strange to say, every other large town had adopted the use of gas before it was introduced into London. Although such a superior light, and so much cheaper than either oil or candles, yet, considering the large amount of dirt produced by its combustion, and also its very disagreeable smell, one is not surprised to find that private families, and especially Londoners, were unwilling

to introduce it into their houses. We may question, indeed, whether it received the attention in London that it did in country towns, for a story is told of a lady of rank who saw it burning in Ackerman's shop in the Strand, and was so pleased with it, that caring neither for its smoke, headache-producing powers, or rotten egg odour, carried it away in her carriage delighted with her purchase.

A Mr. Windsor now determined to organize a public company for supplying London with gas. He managed to get £50,000 from the public, but being a bad chemist, he spent the whole of the money in experiments, the poor shareholders never realizing a farthing for their investment. Something like the bubble companies and discount societies of the present day. A second company was formed, which like the first soon failed. A third, however, succeeded beyond all the brightest anticipations of its friends; and from the gas of this company, in the year 1807, Pall Mall was lighted up, which was the first public street lighted with gas.

And now gas is found in every private house; and every little village has its gasometer. A strange history indeed is that of coal gas—a typical history, if I may call it so, of that strange process of development which we cannot help noticing affects all grand discoveries—all political institutions—as well as all religious systems.

I wish now to draw your attention to this diagram, upon which I have written the principal gases entering into the constitution of coal gas. I have placed hydrogen first, as one of the chief diluents. I will burn a little hydrogen in this bottle, but you see it gives very little light, and the little light it does give is due to the

solid particles floating in the room. Again you will notice carbonic oxide, which I will burn in this bottle, gives also but very little light. So also light carbonetted hydrogen (C_2H_4) which I am burning here. I need not just now refer you to the gases I have classed as impurities. But I must draw your attention very particularly to one gas, viz., olefiant gas, (C_4H_4,) which is one of the most important of the illuminants. I have collected a large bottle full of olefiant gas, which if I inflame, you will notice produces a splendid light. So that you see some gases act as the diluents of other gases, which are the illuminants, of which I have said olefiant gas is the principle. I shall point out, however, directly, that these diluents serve other purposes. Now you will find that the illuminating power of these gases is in direct proportion to the amount of carbon which they contain. Olefiant gas, as you will notice by this diagram, contains 86 per cent of carbon, but carbonic oxide only about 43 per cent. If then it is true that the amount of light varies in proportion to the amount of solid matter—in this case the quantity of carbon—it must also be true, that if we can give a non-illuminating gas solid particles it will become illuminating. And so it is; this hydrogen is colorless—I will pass it through a liquid rich in carbon. In its passage it will seize the solid matter, and you will notice, if I light it now, as it issues from this little apparatus, that the flame is no longer colorless, but produces a bright light. And this is the principle of the carburators which are being used for improving the light from coal gas, and which raises the illuminating power of the gas about 60 per cent over that unnaphthalized, giving continuously

about eight grains of hydrocarbon to each cubic foot of gas. I have placed many varieties of this apparatus on the table.

I have already said that olefiant gas has a greater illuminating power than any other gas obtained during the distillation of coal. Now a candle or an oil-lamp is only a variety of gas-burner, because that tallow or that oil must be converted into a gas before it can be lighted. It was therefore clear that if an oil, or some substance capable of being manufactured into candles, should be discovered similar in composition to olefiant gas, (which I have already stated contains 86 per cent of carbon,) that that would probably be the best material. In other words, if it were possible to condense olefiant gas into a solid or a liquid, then, in that solid or liquid, we should possess the highest conditions for producing a good light. If coal is distilled at a low temperature, a temperature lower than is necessary to form gas, an oil comes over, which is called paraffin oil, and this paraffin oil contains a solid in solution, depositing it when mixed with alcohol, and the whole exposed to a low temperature. This is paraffin—and the candles manufactured from it, specimens of which in all colors are upon the table, are probably familiar to you all. But, strange to say, this liquid and solid paraffin is the same composition as—isomeric with—olefiant gas; that is to say, they are nothing but solid and liquid olefiant gas. Paraffin is a curious substance. No chemical re-agent has any action upon it, neither does it combine in a definite manner with any other body (parum affinis.) It is necessary to be on one's guard in buying the so-called paraffin oils, many sold

as such in commerce containing volatile bodies which take fire at ordinary temperatures, and are very dangerous. True paraffin oil is perfectly safe, as it will only burn in the presence of a wick. I have lately tested many samples of oil sold as paraffin, from the use of which I should not have been surprised had many accidents occurred.

The illuminating gases in coal gas are easily decomposed by heat; the gases which serve as diluents hurry their onward progress from the retort, and so prevent decomposition occurring. The manufacture of coal gas is worth your attention for a moment.

The coal is distilled in cast-iron retorts, which hold from twelve hundred weight to one ton apiece, a large fire maintaining them at a bright red heat. Besides gas, I have already remarked other substances are formed, that collect in the condenser, namely, a watery liquid and the coal-tar. The gas, with which I am just now occupied, is conducted into what is called the "hydraulic main," a large horizontal pipe half filled with liquid, by means of the stand-pipes. The gas now passes through a long series of pipes which, by exposing a large surface to the atmosphere, cools the gas—in some cases they are kept artificially cooled by means of a stream of water playing over them. In these pipes any tar or water which may be held by the gas will be condensed. Passing through "the exhauster," which helps to hasten the rate of the progress of the gas, and prevents the olefiant and other gases being decomposed, it now reaches a cylinder filled with coke, kept wetted by a constant stream, where the gas is washed, as well as any mechanical impurities it may contain got rid of.

This is "the scrubber." The gas still contains carbonic acid, which diminishes its illuminating power, and sulphuretted hydrogen, which gives it a bad smell. To rid it of these the gas passes into the purifier, which formerly was constructed with hydrate of lime, but which material has almost entirely given place to a mixture of sawdust and oxide of iron. The gas is made to pass over a large surface of the purifying substance—water and sulphide of iron being formed. The ammonia should also be got rid of by passing the gas through dilute sulphuric acid. There is still another impurity about which I should wish to say a few words, that is bisulphide of carbon, ($C\,S_2$,) which may be removed by passing the gas over heated lime, when the water of the lime (HO) becomes decomposed; the hydrogen of the water unites with the sulphur of the bisulphide, to form sulphuretted hydrogen, (SH,) which may be removed by the means I have already pointed out, and the oxygen with the carbon to form carbonic oxide. Unfortunately some sulphur always finds its way into the gas holder. Dr. Letheby has proposed an admirable mode of estimating the amount of sulphur in coal gas by burning the gas in an atmosphere of ammonia—when sulphate of ammonia is condensed, from which we can easily calculate the sulphur present, having first changed it into a sulphate of Baryta. The gas is now ready for the gas holder, from which it enters the pipes to supply the town. I regret time will not allow me to say more about coal gas. I must content myself with the few remarks I have made.

I shall not detain you long with the "gas water." This bad smelling gas water is valuable from the salts

of ammonia that it contains; about ten gallons of this water is obtained from the distillation of a ton of coals. The ammonia in the water exists in the form of sulphide of ammonium and carbonate of ammonia. I need not dwell on the characters of ammonia generally. It is, you all know, an alkali, and it is the character of an alkali to combine with an acid. I can illustrate this by bringing some ammoniacal gas which I have collected in one bottle in union with some hydrochloric acid gas which I have collected in another, and you see the quantity of chloride of ammonium formed the moment I bring them in contact. Now sulphuretted hydrogen and carbonic acid are both volatile substances. Hence, from the compounds of ammonia present in the gas water we can obtain any salt we please by the addition of a strong acid. For example, if we add muriatic acid, we obtain muriate of ammonia, which is first crystallized and afterwards purified by sublimation. Upwards of five thousands tons of chloride of ammonium are annually manufactured in this way; sulphate of ammonia is also manufactured by the addition of sulphuric acid, and is very largely used for manure. Carbonate of ammonia is also prepared from the sulphate by admixture with carbonate of lime, and this carbonate of ammonia is the chief ingredient of the Preston smelling salts, with the value of which I have not a doubt many a lady who does me the honour of being present to-day, is practically acquainted. Strange thought indeed, that ladies should, as a desirable and popular luxury, carry in their pockets the products of the filthy smelling gas water. And for this they are indebted to the discoveries of modern chemistry.

"This is an art
Which does mend nature—change it rather."

I have placed on the table many beautiful specimens of the salts of ammonia thus obtained; one especially magnificent sample of the chloride of ammonium, the finest I have ever seen, for all of which I am indebted to Messrs. Clarke and Coste, of S. Mary-at-Hill. But I must pass on to the tar.

This coal-tar yields, on distillation, first, a very volatile substance called *naphtha*—a less volatile substance, *dead oil*—and lastly, one not volatile in the least, *pitch*. In 100 parts of coal-tar, there are 9 parts naphtha, 60 parts of dead oil, and 31 of pitch. The mode of procuring the naphtha is as follows: a current of steam is forced into the retort containing the tar. The water collects in the receiver, with the naphtha floating on the top. The dead oil may be separated from the pitch afterwards by distillation. The naphtha in its crude state is largely employed for dissolving india-rubber. Here I have a specimen of naphtha, and for this and the whole series of the products of coal-tar, (a highly instructive and beautiful collection,) I am much indebted to my very good friend, Mr. Bush, of Liverpool Street.

The *Solid* neutral hydrocarbons obtained from coal-tar naphtha are, amongst others of which little at present is known, naphthalin and paranaphthalin. Here is a specimen of naphthalin ($C_{20}H_8$.)

The *Liquid* neutral hydrocarbons are of much greater interest and importance, and to their chemical history I shall ask your attention for a few minutes. Merely naming those comparatively unimportant, namely, toluol, cumol, cymol, xylol, &c., specimens of some of

which are before you, I pass to the most useful of all, benzol, or benzine, as the ladies call it, and which is extensively employed now-a-days for removing grease spots. Now, fortunately, benzol distils over at a much lower temperature, about 176° F., than any of the other hydrocarbons. The still is kept at about this heat by water placed externally. This benzol was discovered many years ago by Mr. Faraday, and called by him bicarbide of hydrogen. No doubt, in some way, the illuminating power of coal gas may be due to the vapour of benzol, which I have already pointed out as being volatile in the highest degree. Indeed it is largely used for feeding the carburators so much in use at the present time. The composition of benzol is $C_{12}H_6$.

Now if I act on this body with very strong nitric acid, I drive out one of the hydrogens and substitute in its place one of hyponitric acid, (NO_4,) with a composition, as you perceive, of ($C_{12}H_5NO_4$). But the substance now is entirely changed. It had, as benzol, a disagreeable smell, and a still more disagreeable taste; it has become an intensely sweet liquid, with an odour and taste resembling the oil of bitter almonds. I should say it is the essence of bitter almonds. If I pour a little of it on a hot plate I have no doubt the odour will soon be diffused throughout the room; and so, you see, a product of coal has found its way into our ratafia and almond cakes.

Again, if I reduce this nitro-benzol by acting upon it with acetic acid and iron filings, the iron will take away the oxygen to form an oxide of iron, whilst the hydrogen of the water will unite with the hydrogen of the nitro-benzol to form a substance, which of late years

has been fully investigated by Dr. Hoffman, called aniline ($C_{12}H_7N$.)

Now aniline may be obtained from other substances besides nitro-benzol. It is one of the products of the distillation of indigo. It is a powerful base, that is, it will with great ease form crystallizable salts with acids. But, more than this, aniline is strictly analogous to ammonia, and belongs to the series of compound radicles termed phenyl, affording an admirable example of a substitution compound, where one of the hydrogen of the ammonia (NH_3) has been substituted by one of phenyl, $C_{12}H_5$ — Ammonia = $N\ H_3$: Aniline = $N\ H_7\ C_{12}$; or we may show the action better thus :—

$$\text{Ammonia} = N\begin{cases} H \\ H \\ H \end{cases} \quad \text{Aniline} = N\begin{cases} H \\ H \\ C_{12}H_5 \end{cases}$$

The history of aniline, its character, formation, and compounds, is tempting, but I must not linger over them. Now I will take a small quantity of this compound ammonia—this aniline, (7 or 8 drops will answer our purpose, though there is no reason why I should be so economical in its use,) and add to it a solution of chloride of lime. Notice the result; gradually (the color will soon be more apparent) there is produced a beautiful purple violet color, which is already becoming very deep. You will notice, however, it is rapidly changing to a dirty reddish brown. This is a very important experiment. It was noticing this beautiful color, that made Mr. Perkin set to work to render it permanent; I have already said that aniline is a powerful base, and taking advantage of this fact, Mr. Perkin first formed

a sulphate of aniline, which he mixed with bichromate of potash, when he obtained this substance that I now produce. This is washed first with water, and afterwards with naphtha, and then dissolved in alcohol, and there is produced a solution of the lovely coloring matter we call mauve. Here are specimens of crystals of this beautiful substance sent me by Mr. Bush, and also by Messrs Roberts, Dale, and Co., of Manchester. Ladies can easily dye their silks with this aniline purple, by merely dipping them in a nearly boiling solution of tartaric acid, with the addition of a little of the coloring matter.

Magenta is prepared by the action of some weaker oxidizing agent on aniline ; dry hydrated arsenic acid being ordinarily employed for this purpose. This is heated for some hours, when this brown looking matter is obtained, which after being dissolved in water, treated with soda, and then dissolved in acetic acid, forms the acetate of rosaniline—the salt which is usually found in commerce. I have on the table some fine specimens of the crystals. This magenta is a true base, which in its combination with acids, forms beautiful colored salts. Here, too, are numerous specimens of other aniline colors, which I had intended to have said a little about if time had permitted it, the Blue de Paris and the new greens, and here also are samples of silk dyed with these colors, kindly sent me by Mr. J. N. Krauss, and these magnificent specimens by Mr. Keith. These colors go a very long way. Ten grains of magenta will dye two square yards of silk. I can illustrate its tinctorial powers by projecting a stream of alcohol on these papers, upon which I have dusted a little of the

coloring matter, which is not apparent at present, but will instantly become so when taken up by the alcohol.

Just a word about the acid portion of the coal-tar oil, carbolic acid, or phenol, and its homologue, cressylic acid. The mixture of these two acids forms, creosote, the principle to which wood smoke owes its powers of curing and preserving provisions (κρέας and σώζω). This carbolic acid, if purified and dried, forms a solid crystalline substance, a beautiful specimen of which, by the kindness of Mr. Bush, I am able to show you. Carbolic acid is a powerful disinfectant. You all remember how largely it was employed during the late visitation of Cholera, and considering that its smell is not most agreeable, we were soon able to discover where it had been used.

If we treat carbolic acid with nitric acid, three equivalents of the hydrogen of the carbolic acid ($C_{12}H_5O, HO$) are turned out, and their place taken by three equivalents of a compound radicle which plays the part of the hydrogen. And in this way we form the beautiful yellow coloring matter, carbazotic acid. Here is the acid, and here is some silk that has been dyed with it. I ask you, is not this

> " An art, which, in its piedness shares.
> With great creating nature;
> An art
> Which does mend nature—change it rather ? "

I much regret my hour is gone; I must not detain you longer, as the pantomime is about to commence, though I believe the transformations I have introduced to you are quite as curious, quite as pantomimic, as any-

thing you will have the opportunity of witnessing on the Palace stage, and with the pre-eminent advantage of being, under its brightest aspect, stamped with permanence. Do not then the changes of coal-tar form a wonderful and truly beautiful chemical transformation scene?

Printed at the Operative Jewish Converts' Institution, Palestine Place,
Bethnal Green, N.E.